GEOMETRY IN THE METAVERSE: ARE HIGH SCHOOL TEACHERS RESPONSIVE TO CHANGE?

Maria Rosaria Del Sorbo, Maria Giuseppina Adesso, Roberto Capone, Oriana Fiore, Giovanna Quercitelli

L. Da Vinci High school, Poggiomarino (NA), Italy; marodeldue@gmail.com

Da Procida High School, Salerno, Italy; mapinadesso@gmail.com

University of Bari Aldo Moro, Bari, Italy; roberto.capone@uniba.it

University of Salerno, Fisciano (SA), Italy; ofiore@unisa.it

Armand Diaz high school, Ottaviano (NA), Italy; giovanna.quercitelli@gmail.com

ABSTRACT

The emerging metaverse technology, recent evolution of Virtual Reality, is displaying the potential to deeply change specifically the educational world. The metaverse is a virtual place where it is possible to experience a novel way to teach and learn in immersive spaces. This paper, after an introduction about the Technological Pedagogical Content Knowledge, a theoretical lens to interpret the data, examines the willingness of high school Maths teachers to exploit metaverse in their teaching and draws on a survey to assess their awareness and attitude towards metaverse technology in geometry education. A qualitative analysis carried out from an anonymous questionnaire that involved 25 Italian teachers about the metaverse. The survey results indicate that high school teachers are aware of the potential of metaverse in teaching geometry but lack the confidence and resources to exploit it. The paper concludes by suggesting strategies for training and equipping high school teachers to use metaverse in geometry education and some considerations about psychological aspects of learning geometry in immersive classrooms.

Keywords: Metaverse, geometry teaching, visualization, teachers' professional development

INTRODUCTION AND RATIONALE

Many studies have been carried out about the difficulties encountered by students in geometry. These difficulties refer to such basic geometric concepts as the angle, triangle and quadrilateral (e.g., Hershkowitz, 1987; TIMSS, 1999), as well as advanced assignments such as deductive thinking and proofs (e.g., Lin, 2005). The difficulties are analyzed in several perspectives: cognitive and developmental theories such as the van Hiele theory (Burger & Shaughnessy, 1986; Kouba et al., 1988), orientation (Hershkowitz, 1989b), and concept formation (Hershkowitz, 1987; Tall & Vinner, 1981). In geometry learning, visualization is crucial. Del Grande (1990) claims that "Geometry has been difficult for pupils due to an emphasis on the deductive aspects of the subject and a neglect of the underlying spatial abilities" (p. 19). Gal et Linchevski (2010) considered theories about processes of visual perception and perception-based knowledge representation to explain difficulties in figural processing in high school geometry tasks. Another Gal's study (2005) suggests that the theoretical perspective of Problematic Learning Situation could become part of teachers' pedagogic content knowledge, so that the teachers could acquire the ability to analyze and cope with their students' difficulties in geometry. Markey (2009) in his dissertation highlighted the relationship between visual-spatial reasoning ability and Mathematics and Geometry Problem-Solving. Studies on Augmented Reality, (Capone and Lepore, 2020; Capone et al., 2022), highlighted how the possibility of exploring mathematical objects generated by a computer motivates students to explore and interact with mathematical objects being able to understand more deeply. Past Virtual Reality experiences also produced encouraging results, supporting the improved easiness in the conceptualization of mathematical objects through an immersive visual interaction. In fact, virtual reality is a completely virtual environment, where the user can interact in an immersive and bidirectional way with virtual objects and environments, using VR viewers and other input devices. However, the VR experience is limited to the single and there is not necessarily a social component of interaction with other users. The world of education is ever-evolving, and with the fast diffusion of Metaverse in recent years, there is an opportunity to use technology to introduce a new way to teach and learn. Gartner, a technological research and consulting firm, has predicted that by the year 2026, one quarter of the population will be dedicating at least one hour of their day to activities in the metaverse. By the way, this includes work experiences based on the platforms that were adopted during the pandemic to enable people to work remotely. Metaverse technology provides an immersive 3D environment, allowing a virtual but strong sensation of objects, data, and other digital content in a realistic and engaging way. The Metaverse (Lee, 2021) is a virtual environment that is designed to be a simulation of the real world. It is a network of 3D worlds created in real time, allowing many people to enter at once. It is a place where people can communicate, work, learn, chat, relax, and attend virtual concerts. It combines real world and virtual worlds, allowing for lifelike interaction in virtual workplaces. Through the use of hardware and software, the Metaverse is able to provide a platform for people to engage in activities such as traveling, playing, working, and running. It is a concept that is still being discussed and developed, but its potential is exciting. The Metaverse could be the future of communication and collaboration, offering an immersive and interactive experience. The main differences between AR and VR, technologies that have been gaining traction in recent years, and metaverse are:

1. Metaverse is a virtual world, while AR is a technology allowing users to interact with virtual objects in the real world.
2. Metaverse is a persistent, interconnected virtual world, while AR and VR are more focused on creating immersive experiences.
3. Metaverse is a shared virtual space, while AR and VR are more focused on individual experiences.
4. Metaverse is a platform for creating virtual communities, while AR and VR are more focused on creating virtual environments.

Beyond it, the metaverse is a platform that allows people to interact with each other in a virtual world, while virtual reality (VR) is a technology that enables users to experience a simulated environment. The two differ in terms of platform interpretation, technological constraints, possession of 3D entities, user convenience of virtual spaces, and the tenacity of shared virtual worlds. In terms of platform interpretation, the metaverse is a cross-platform experience, while VR requires the use of specific hardware devices such as headsets or goggles. Technologically, VR has limitations in terms of virtual reality simulations, while the metaverse has no such restrictions. Additionally, the metaverse allows users to own virtual objects, while VR does not. In terms of user convenience, the metaverse is an open environment, while VR requires the use of a headset or glasses. Finally, the metaverse is still in its early stages, while VR is more established. Overall, the metaverse and virtual reality are two distinct technologies that offer different experiences. While the metaverse is still in its infancy, VR is more established and has been gaining traction in recent years. To learn more about the future of immersive realities, it is best to consult experts in the field. The Metaverse is a concept that goes beyond the individual user experience of virtual reality and augmented reality, and instead seeks to create a shared and persistent virtual world in which people can interact with one another in a way that mirrors the interactions of the physical world. This virtual environment would be accessible to multiple users at the same time, allowing them to engage in activities such as socializing, gaming, and commerce. The Metaverse would be a place where people can come together to share experiences, collaborate on projects, and explore new ideas and besides where they could create their own virtual identities and build relationships with others and explore the possibilities of a virtual world without the limitations of the physical world (Zhang, 2022; Parsons 2019) This tool seems to be specifically suitable to high school geometry education (Eşin, 2022; Dwivedi , 2022; Zheng, 2023; Park, 2022; Carneiro 2021) , because, as emerged in analyses of National Standardized Tests, students show the most strong difficulties in answering questions about posing and solving geometric problems and they are very often discouraged by the complexity of spatial concepts and proofs of Euclidean geometry in 3D and analytic geometry in space. Educational innovation means looking for new and updated resources, particularly drawn from new technologies, able to make learning more immediate, persistent and deeper, by appealing to students' curiosity and motivation and using the most closer to reality possible tools (Ausubel, 1968; Mueller, 1974) and then gradually moving to more abstract levels. In this process, teachers are the authentic drivers of all innovation (Frost D., 2016): they have to face a dizzyingly advancing world, to take into account new educational demands and to exploit the latest communication media and technology to best achieve their teaching goals. Therefore, as a result, some teachers may spontaneously show an attitude to frequently update their professional training and acquire skills in a lifelong learning perspective. Experimentation in classrooms is only the last step of the process, which, given the current rhythm of development, requires short time and commitment. In particular, teachers can introduce new ways to facilitate learning and enhance the level of interaction in the classrooms (Nguyen, 2020) they can exploit the pervasiveness and popularity of social media, educational games, collaborative projects, group work, laboratories. This work is focused on teacher professional development related to an immersive experience in the Metaverse of a focus group composed by 25 Maths teachers, in order to experiment the potential of metaverse in high school teaching of geometry of three-dimensional, Euclidean space and analytic geometry in Cartesian space. The purpose of the study is twofold: from the perspective of mathematics teaching, it is to give teachers hands-on experience with the features of Metaverse in order to be able to design activities to teach 3D Geometry. The purpose of the research is to analyze how Technological Knowledge should be integrated with Content Knowledge and Pedagogical Knowledge in order to give effective training to the mathematics teacher with respect to the technological challenges of the 21st century and to the most familiar to today's pupils' technologies.

THEORETICAL FRAMEWORK

The teacher's role is fundamental in helping students to construct mathematical meanings (Capone et al., 2018). For this reason, in this experimentation, many complex aspects related to the use of intersections between technological knowledge, Pedagogical knowledge and content knowledge in teaching were taken into account. This paper referred to the Technological Pedagogical Content Knowledge (TPACK) framework conceived by Shulman in 1986 to define the elements that can characterize teaching when supported by technologies without neglecting the pedagogical aspects and the specific teaching contents of the discipline. In 1986, Shulman introduced pedagogical content knowledge that includes pedagogical knowledge and content knowledge, among other categories (Shulman, 1986). In 2001, Pierson added technological content to these categories. He illustrated the T.P.C.K. model as the intersection of three sets representing three knowledge domains: Technological Knowledge, Pedagogical Knowledge, and Content Knowledge (Pierson, 2001). Gess-Newsome (1999) refers to an integrative model and a transformative model. The transformative model is analogous to a chemical compound, which resists easy separation of its components. Gess-Newsome describes it as “being inextricably combined into a new form of knowledge.” The integrative model is analogous to a chemical mixture as components retain their identities, but they are indistinguishable on a macroscopic level; the teacher selects knowledge from three domains combining them as necessary to teach. Mishra & Koehler (2006) describe the intersection between T.K. and C.K., P.K. and C.K., T.K. and P.K., they clarify the meaning of the intersections between Technology, Pedagogy, Content, and Knowledge, as the below figure shows.

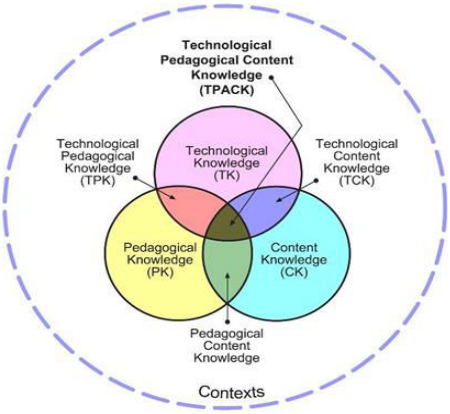

Figure 1: T.P.A.C.K. Venn diagram

They state: “Pedagogical content knowledge (P.C.K.) is concerned with the structure, organization, management, and teaching strategies for how the particular subject matter is taught. Technological content knowledge (T.C.K.) is related to how a particular subject matter is represented in technology-rich environments. Teaching with technology requires knowing the subject and how subject matter can be changed with technology application, and this knowledge is called T.C.K. Technological pedagogical knowledge (T.P.K.) is concerned with teaching and learning change due to integrating technology into instruction and choosing a particular tool for a particular task considering its affordances and limitations. Technological Pedagogical Content Knowledge (T.P.A.C.K.) is an emergent form of knowledge beyond all three components (p. 1028). According to transformative models, T.P.A.C.K. is different from knowledge of a disciplinary or technology expert and also from the general pedagogical knowledge shared by teachers across disciplines (p. 1029)”. This model helps to read some results generated and developed from the collaboration of different actors of the educational scene: teachers, researchers, and I.T. developers, as highlighted in a recent article on Dynamic Geometry System (Ferrarello et al., 2017). It helps us interpret the teachers' attitude towards innovation in teaching by inserting the Metaverse into classroom practices. Indeed, teachers face a difficult challenge: they must integrate the knowledge of pedagogical contents, knowledge of teaching process, knowledge of technological contents that refers to how technology can create new representations for specific content, technological pedagogical knowledge that refers to various technologies used in teaching. Recent studies aimed to develop and validate a T.P.A.C.K. scale to investigate mathematics teachers’ knowledge levels in T.P.A.C.K. components, whether the mathematics teachers’ T.P.A.C.K. levels differed in terms of gender, teaching experience, and school level, with a particular focus on primary and secondary mathematics teaching (Ozudogru & Ozudogru, 2019).

METHODS

Participants.

Our experiment involved 25 mathematics high school teachers, aged between 25 to 62 years, teaching in Italian scientific high schools. Their age was 48 years in average, and they have been teaching for about 15 years

Methodology

A qualitative analysis was conducted based on the researchers' observations during the experimental phase and on the results of an anonymous questionnaire administered to teachers after the experience. In addition, a quantitative analysis of some questions set on a Likert scale was performed. The questionnaire was divided into three sections:

Section A: questions about teachers' personal data (in order to gain characterization of their profiles);

Section B: questions about teachers' technological, educational and methodological skills. (close questions); Section C: questions about teachers' technological, educational and methodological skills. (open questions).

Activities

Teachers experienced directly the potential of the metaverse through an immersive experience focused on the geometry of space. They were introduced in the Spatial platform for Metaverse, a development platform aimed at enabling developers to easily create multi-user immersive experiences based on virtual reality. Using the platform, one can easily create, deploy and manage a 3D virtual world, including environments, 3D models, audio, animations, augmented reality content and more. The Spatial platform for Metaverse also offers APIs for creating multi-user content and creating augmented reality applications. Two researchers in Didactics of Mathematics supervised the teachers in this experience. A researcher invited teachers in remote locations to join the group in the space called 3D Geometry experience (https://www.spatial.io/s/3D-Geometry-Experience 63fa714e0d2149f421d09c28?share=2505555477767704289) where teachers tried a first taste of what Metaverse could be like.

RESULTS AND DISCUSSION

This study seems to confirm the study conducted by Borromeo et al. (2019) that highlights the importance of teachers' ICT literacy in developing their pedagogical techniques and incorporating technology in their teaching practices. The TPACK model, which integrates content knowledge, pedagogical knowledge, and technological knowledge, is essential for teachers to effectively plan, reflect, and adapt their teaching practices. However, the lack of school facilities in some areas hinders teachers from developing their technology skills, which subsequently affects their TPACK. The graphs below show how much teachers feel familiar with the Metaverse and how up-to-date teachers feel about the Metaverse experiences in educational applications.

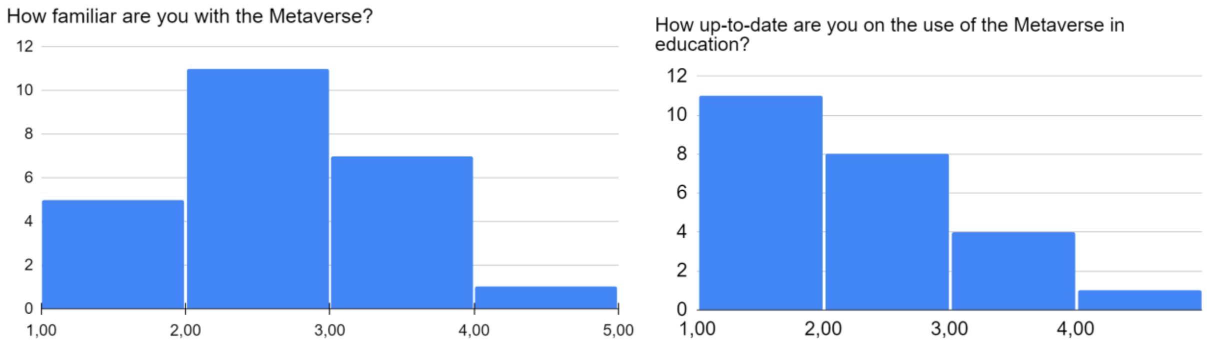

Figure 2: Graphs about how teachers use Metaverse

Observing both the graphs and reflecting upon some of the teachers' answers, we can conclude that the most part of them are unacquainted with the new metaverse technology and are also not very familiar with other technologies such as augmented reality and virtual reality. They claim that they have to face more daunting teaching problems by far.

T1: These new technologies are very fascinating. The metaverse for example might be nice but we are facing bigger problems. Using these technologies involves a very fast internet connection, a lab always available, and challenging continuous professional training.

T2: It is not easy to think of using advanced technological tools without having adequate training, funds and time available.

In a nutshell, not only are some institutions not equipped with technology, but also teachers feel that they are not always adequately trained about the latest ICT. In contrast, many teachers have a positive attitude towards technological developments and show better ICT literacy skills in the use of metaverse, which enhances their teaching process. Here below we show graphs summarizing teachers' opinions regarding the use of immersive tools such as Virtual Reality and Metaverse to improve students' understanding of 3D geometry topics and their performance in objective tests.

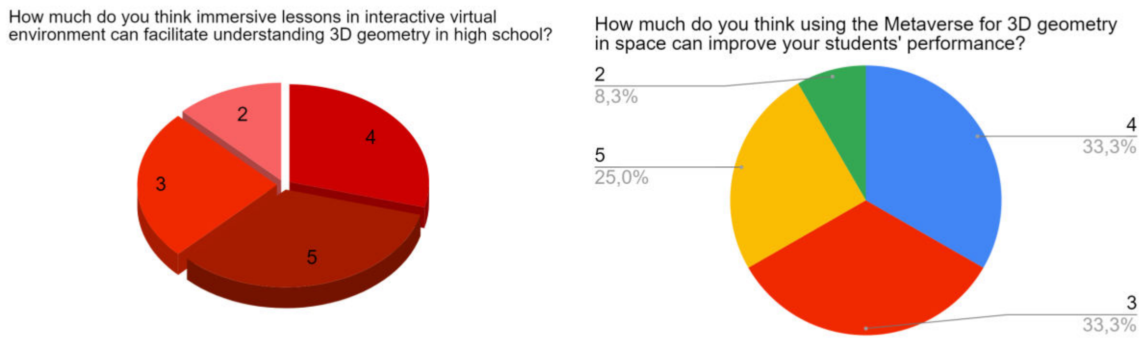

Fig. 3 Teachers opinion about use of Metaverse for teaching Geometry

However, even those teachers who are more familiar with technology state they have never used the metaverse for teaching geometry but are willing to experiment with its potential and then use it in the classroom with their students.

T3: It would be very interesting to learn how to use these technological tools. First of all, for our professional training. This would definitely have a positive impact on students' skills

T4: using tools that can help students study geometry more willingly would be great! At the last National Standardized Tests, my students encountered difficulties with geometry questions specifically.

Some teachers say that in today's society it is crucial to experiment near the last frontiers because technology is in the student's daily experience and the school cannot ignore it if it wants to stay one step ahead and to find effective means of communication with the new generation.

T5: I think it is crucial to give students opportunities, and using technologies such as the Metaverse to establish effective communication with them can be a good way to engage them.

T6: Certainly, welcome the use of the metaverse if it can bring students closer to the study of mathematics and if it can facilitate conceptualization. But it all has to start with solid teacher training.

T7: The use of technologies cannot be improvised, it requires adequate pedagogical knowledge or theoretical tools that make the teacher aware of the use of a new resource such as the metaverse.

The chart below summarizes what emerges from the open-ended responses about teachers' motivation to use the metaverse in teaching geometry:

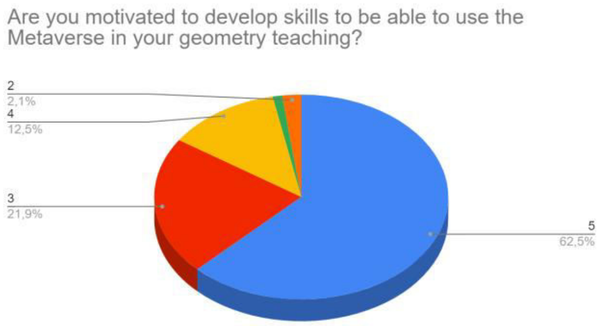

Fig. 4 Teachers opinions about their motivation to use Metaverse

The study suggests that the synergy between dynamic content knowledge and technology applied in the use of metaverse plays a significant role in developing teachers' TPACK. Therefore, it is essential to provide teachers with adequate resources and training opportunities to improve their skills and incorporate metaverse in their teaching practices effectively. By doing so, teachers can enhance their pedagogical techniques, promote creativity and critical thinking, and provide a better learning experience for their students.

CONCLUSIONS

Technological Pedagogical Content Knowledge (TPCK) is a framework that describes the knowledge and skills required by teachers to effectively integrate technology into their teaching practices. This framework emphasizes the importance of understanding the intersection of technology, pedagogy, and content knowledge in teaching and learning. Metaverse is a platform that allows users to create and share their own interactive augmented reality experiences. It provides an innovative approach to education by allowing students to engage with content in new and exciting ways. Several studies have explored the application of the TPCK framework in using Metaverse for educational purposes. This study found that teachers who had a high level of TPCK were more likely to effectively use Metaverse in their teaching practices. These teachers were able to create engaging and interactive learning experiences that effectively integrated technology, pedagogy, and content knowledge. The study also found that teachers who were less experienced with technology needed additional training and support to effectively use Metaverse in their classrooms. Overall, these studies demonstrate the potential of Metaverse as a platform for innovative and effective teaching practices. They also highlight the importance of the TPCK framework in supporting teachers to effectively integrate technology into their teaching practices.

REFERENCES

Ausubel, D. P. (1968). The influence of experience on the development of intelligence. *Productive thinking in education*, 6-62.

Capone, R., & Lepore, M. (2020). Augmented reality to increase interaction and participation: A case study of undergraduate students in mathematics class. In *Augmented Reality, Virtual Reality, and Computer Graphics: 7th International Conference, AVR 2020, Lecce, Italy, September 7–10, 2020, Proceedings, Part II 7* (pp. 185-204). Springer International Publishing.

Capone, R., Lepore, M., & Mennuni, F. (2022). Characterising paraboloids using Augmented Reality. *Mathematics Education in Digital Age 3*, 80.

Carneiro, M., Aires, A. P., & Campos, H. (2021). Learning to teach geometry at a distance: Digital resources for the development of geometric reasoning. In EDULEARN21 Proceedings (pp. 5796-5803). IATED.

Dwivedi Y.K., et al., (2022), Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy, *International Journal of Information Management*, Volume 66, 2022, 102542.

Eşin, Ş. & Özdemir, E. (2022). The Metaverse in mathematics education: The opinions of secondary school mathematics teachers . *Journal of Educational Technology and Online Learning , ICETOL 2022* Special Issue , 1041-1060 . DOI: 10.31681/jetol.1149802.

Frost, D. (2016). From professional development to system change: Teacher leadership and innovation. In *Teacher Leadership and Professional Development* (pp. 45-67). Routledge.

Hershkowitz R., (1987), The acquisition of concepts and misconceptions in basic geometry - or when "A little learning is dangerous thing", *Proceedings of the Second International Seminar--Misconceptions and Educational Strategies in Science and Mathematics*, vol. 3, 1987, pp. 238–5.

Lee, L. H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., ... & Hui, P. (2021). All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda. *arXiv preprint arXiv:2110.05352*.

Lin, W. L., Lien, Y. W., & Jen, C. H. (2005). Is the More the Better? The Role of Divergent Thinking in Creative Problem Solving. *Chinese Journal of Psychology*.

Mueller, R.J. (1974). *Principles of Classroom Learning and Perception* (1st ed.). Routledge. https://doi.org/10.4324/9781315202440.

Nguyen, D., & Ng, D. (2020). Teacher collaboration for change: Sharing, improving, and spreading. Professional development in education, 46(4), 638-651..

Park S., Kim Y., (2022), "A Metaverse: Taxonomy, Components, Applications, and Open Challenges," in *IEEE Access*, vol. 10, pp. 4209-4251, 2022, doi: 10.1109/ACCESS.2021.3140175.

Parsons, K.M.a.D. (2019). Teacher Perspectives on Mobile Augmented Reality: The Potential of Metaverse for Learning. In Proceedings of World Conference on Mobile and Contextual Learning 2019 (pp. 21-28).

Yeh, A. & Nason, R. (2004). Knowledge Building of 3D Geometry Concepts and Processes within a Virtual Reality Learning Environment. In L. Cantoni & C. McLoughlin (Eds.), *Proceedings of ED-MEDIA 2004--World Conference on Educational Multimedia, Hypermedia & Telecommunications* (pp. 2175-2182). Lugano, Switzerland

Zhang, X., Chen, Y., Hu, L., & Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. F*rontiers in Psychology*, 13.

Zheng G., Yuan L., (2023), A review of QoE research progress in metaverse, *Displays*, Volume 77, 2023, 102389.